1   What is claimed is:

2

3   1.   A method of monitoring the capacity of a valve regulated lead acid battery, comprising:

4   connecting at least one battery monitor to said valve regulated lead acid battery;

5   connecting said monitor to a centralized system through an industry standard data system

6   that collects and transfers data from the field to a central office;

7   providing said centralized system with an alarm;

8   performing a short-term discharge test on said battery using said battery monitor; and

9   obtaining a predicted capacity using a neural network and fuzzy logic network in

10   combination with a prediction algorithm;

11   wherein, said discharge test provides input parameters for said networks which in

12   combination with said prediction algorithm calculate said predicted capacity, and wherein, said

13   alarm is activated when said predicted capacity falls below eighty percent, when an individual cell

14   voltage is reduced to 1.95 volts or less, or when a system failure occurs.

15   2.   A method as in claim 1, wherein said battery monitor consists of hardware for monitoring

16   the voltages of each battery cell and currents that are flowing into and out of said battery.

17   3.   A method as in claim 1, wherein said battery monitor contains a serial port enabling data to

18   be downloaded onto a network, computer, or printer.

19   4.   A method as in claim 3, further comprising a real time clock.

20   5.   A method as in claim 4, wherein said real time clock is automatically verified and updated

21   through said network.

22   6.   A method as in claim 1, wherein said discharge test is a four hour discharge test.

1   7.   A method as in claim 1, wherein said discharge test collects specific data parameters

2   including the cell age, open circuit voltage, voltage after one hour of discharge, voltage after three

3   hours of discharge, and voltage after four hours of discharge.

4   8.   A method as in claim 7, wherein said parameters are used to derive three additional data

5   points including the slope of the discharge curve, the delta between voltages at three and four hours,

6   and the proximity to two volts of the four hour voltage.

7   9.   A method as in claim 1, wherein said discharge test is performed on a repeated basis.

8   10.   A method as in claim 1, wherein said neural network is trained for a specific battery type in

9   a lab by determining the actual capacity of a battery, inputting said parameters with the actual

10   capacity used as a target, and programming the set of coefficients yielded by said neural network

11   into an EEPROM which is inserted in said battery monitor.

12   11.   A method as in claim 10, wherein said actual capacity is determined by the following

13   formula:

14   (time to discharge to 1.75V X 24 hour discharge rate)/(24 X 24-hour discharge rate in

15   amps).

16   12.   A method as in claim 10, wherein said neural network is trained only once.

17   13.   A method as in claim 1, wherein said fuzzy logic network comprises:

18   dividing total battery capacity into capacity spans of ten percent;

19   associating a voltage range with each of said ten percent spans, wherein said voltage range

20   was previously determined from said 24-hour rate discharge lab tests;

21   determining within which of said capacity spans said voltage ranges fall by comparing each

22   of said open, one, three, and four hour cell voltages with the known base lines for the specific

23   battery type;

1   determining the strength value of the cell's voltage within a particular span;

2   determining the capacity range with the most positive strength value;

3   adjusting the range that is immediately above said capacity range with most positive strength

4   value by adding the strength value of said range to the lowest capacity value of said range to yield

5   the upper capacity limit;

6   adjusting the range that is immediately below said capacity range with most positive

7   strength value by subtracting the strength value of said range from the highest capacity value of

8   said range to yield the lower capacity limit;

9   wherein, said difference between said upper capacity limit and said lower capacity limit

10   yields the fuzzy logic capacity range span.

11   14.   A method as in claim 13, wherein said strength value is determined as follows:

12   calculating the average voltage for each capacity range using the maximum and minimum

13   voltage values;

14   dividing the cell test voltage (open, one, three, or four hour) by said average voltage;

15   subtracting the quotient of previous step from one and taking the absolute value of the

16   difference;

17   performing this calculation for each of said cell test voltages--open ,one, three, and four

18   hour;

19   adding the calculated values for each of said cell test voltages and dividing the sum by

20   seventy; and

21   subtracting the quotient of the previous step from one;

22   wherein, the value of said strength value can be positive or negative.

23   15.   The method of claim 1, wherein said neural network comprises:

1   inputting parameters including open, one-hour, three-hour, and four-hour cell voltages and

2   the age of said battery;

3   obtaining three more data points from said parameters including slope of the discharge

4   curve, the delta between voltages at three and four hours, and the proximity to two volts of the four

5   hour voltage;

6   outputting a number between zero and one;

7   wherein, said neural network performs calculations as any standard neural network using the

8   coefficients determined from said training of said network using lab data; and

9   wherein, the output of said neural network is multiplied by the span of the capacity range

10   obtained from the fuzzy logic network and adding this product to said lower capacity limit in order

11   to determine the final capacity predicition.

12   16.   An apparatus for monitoring the capacity of a valve regulated lead acid battery, comprising:

13   at least one battery monitor connected to said valve regulated lead acid battery;

14   a centralized system connecting said battery monitor through an industry standard data

15   system to a central office;

16   an alarm connected to said centralized system;

17   wherein, said battery monitor contains a neural network and a fuzzy logic network used in

18   combination with a prediction algorithm; and

19   wherein, said battery monitor contains a means for acquiring all data needed for said

20   prediction algorithm.

21   17.   An apparatus as in claim 16, wherein said battery monitor consists of hardware for

22   monitoring the voltages of each battery cell and currents that are flowing into and out of said

23   battery.

1   18.   An apparatus as in claim 16, wherein said battery monitor contains a serial port enabling

2   data to be downloaded onto a network, computer, or printer.

3   19.   An apparatus as in claim 18, further comprising a real time clock.

4   20.   An apparatus as in claim 19, wherein said real time clock is automatically verified and

5   updated through said network.

6   21.   A method of monitoring the capacity of a valve regulated lead acid battery, comprising:

7   connecting at least one battery monitor to said valve regulated lead acid battery;

8   connecting said monitor to a centralized system through an industry standard data system

9   that collects and transfers data from the field to a central office;

10   providing said centralized system with an alarm;

11   performing a short-term discharge test on said battery; and

12   obtaining a predicted capacity using a neural network and fuzzy logic network in

13   combination with a prediction algorithm;

14   wherein, said discharge test comprises a four hour discharge of said battery, performed at a

15   discharge rate calculated from the amp-hour size of the battery and a 24-hour period, during which

16   specific data parameters consisting of cell age, open circuit voltage, voltage after one hour of

17   discharge, voltage after three hours of discharge, and voltage after four hours of discharge are

18   logged and three additional parameters including three hour slope, the delta between the three and

19   four hour voltages, and the proximity to two volts of the four hour voltage are determined; and

20   wherein said neural network is trained in a lab by determining the actual capacity of a

21   battery using the following formula:

22   (time to discharge to 1.75V X 24 hour discharge rate)/(24 X 24-hour discharge rate in

23   amps),

1   inputting said parameters with the actual capacity used as a target, and programming the set

2   of coefficients yielded by said neural network into an EEPROM which is inserted in said battery

3   monitor; and

4   wherein, said fuzzy logic network comprises dividing total battery capacity into capacity

5   spans of ten percent; associating a voltage range with each of said ten percent spans, wherein said

6   voltage range was previously determined from said 24-hou rate discharge lab tests; determining

7   within which of said capacity spans said voltage ranges fall by comparing each of said open, one,

8   three, and four hour cell voltages with the known base lines for the specific battery type;

9   determining the strength value of the cell's voltage within a particular span by the following steps:

10   calculating the average voltage for each capacity range using the maximum and

11   minimum voltage values; dividing the cell test voltage (open, one, three, or four

12   hour) by said average voltage; subtracting the quotient of previous step from one and

13   taking the absolute value of said answer; performing this calculation for each of cell

14   test voltages (open one, three, and four hour); adding the calculated values for each

15   of said cells test voltages and dividing the sum by seventy; and subtracting the

16   quotient of the previous step from one;

17   determining the capacity range with the most positive strength value; adjusting the range that is

18   immediately above said capacity range with most positive strength value by adding the strength

19   value of said range to the lowest capacity value of said range to yield the upper capacity limit; and

20   adjusting the range that is immediately below said capacity range with most positive strength value

21   by subtracting the strength value of said range from the highest capacity value of said range to

22   yield the lower capacity limit; wherein, said difference between said upper capacity limit and said

23   lower capacity limit yields the fuzzy logic capacity range span; and

1   wherein, said neural network comprises inputting parameters including open, one-hour, three-hour,

2   and four-hour cell voltages and the age of said battery; obtaining three more data points from said

3   parameters including slope of the discharge curve, the delta between voltages at three and four

4   hours, and the proximity to two volts of the four hour voltage; and outputting a number between

5   zero and one; wherein, said neural network performs calculations as any standard neural net using

6   the coefficients determined from said training of said network using lab data; and wherein, the

7   output of said neural network is multiplied by the span of the capacity range obtained from the

8   fuzzy logic network and adding this product to said lower capacity limit in order to determine the

9   final capacity prediction.

10

11

12

13

14

15

16

17

18

19

20

21

22

23